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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Free Piston Engine

We, GEWERKSCHAFT EISENHUTTE WESTFALIA, a German Body Corporate of Wethmar, Near Lünen, Westfalia, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a free-piston engine.

Free-piston engines are already known which have pistons freely movable in cylinders and driven by compressed air for the production of rectilinear mechanical oscillations for conveying devices and the like, and wherein control of the engines is effected by auxiliary means influenced by the operation of the engines.

The invention consists in a free-piston engine for producing rectilinear mechanical oscillations by means of a freely-moving reciprocable working piston which is bi-laterally stepped and the two reduced-diameter ends of which engage in ends of a working cylinder which are associated with the piston ends and form the working chambers, while a central, larger-diameter collar part of the working piston forms a common driving means for control members of two Diesel two-stroke parts of the engine and is surrounded by an annular cylindrical chamber which forms a fresh-air admission chamber and is provided with air-inlet valves controlled by the piston collar part, the engine being characterised by the provision of air admission ducts formed centrally in the working piston and having non-return valves and leading to the end faces of the piston, and transverse ducts which are connected to the air admission ducts and start in front of the piston collar part and open behind it into the said annular chamber.

The control elements acted upon by the free piston collar may, in addition to the air inlet valves, be the pistons of pumps in a fuel supply line, the drive of which and the consequent fuel pressure preferably effecting the injection of fuel into the working chambers of the engine by opening a spring-loaded needle-nozzle valve.

Through the agency of the pump pistons operated by the free piston collar, control pistons are preferably driven, by means of which pistons self-closing fuel admission valves in the fuel lines to the engine cylinder are to be opened.

The control pistons for the fuel admission valves preferably are movable at the same speed as the pump pistons in the opening direction of the valves, but in the opposite direction are movable more slowly owing to the provision of a flow delaying device.

The delaying device for the control pistons may be an oil circulation or regulating device which permits movement of the pistons in the opening direction of the fuel admission valve by automatic opening of a non-return valve, but delays the piston movement in the opposite direction for closing the non-return valve and passage of the oil through a throttling orifice which preferably is adjustable.

The engine may be provided with an energy-storing means which preferably is in the form of a compressed-air container connected to the cylinder ends and is chargeable by the engine and also from outside, and by means of which the engine can be started from the stopped condition with its free piston in any desired position.

The engine may also contain in its fresh-air annular admission chamber only the air outlet valves controlled by the collar of the working piston, and the pump pistons which effect fuel admission, preferably by way of needle valves into the cylinder ends, may be adapted to be acted upon by connecting pipes from the working chambers of the

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engine. The pistons, which are displaceable in cylinders and which control the movement of the fuel admission valves in the fuel line, are adapted to be acted upon by a pipe also connected to the working chambers of the engine.

The pistons which effect the fuel injection and which are displaceable in a cylinder may be two-diameter pistons the larger diameter part facing towards the engine cylinder being subjected to the action of a spring in the direction opposite to its admission direction, whilst the smaller diameter part engages in an appropriate cylinder chamber which is connected to the fuel admission line and from which the fuel to be injected into the engine is always displaced.

The fuel admission valve control device, consisting of a cylinder with a piston displaceable in it, preferably contains in the line to the engine cylinder, a non-return valve which permits the unhindered action of pressure on the control piston and which in conjunction with an air throttling orifice provided in the cylinder retards the movement of the control piston in the opposite direction.

Between the fuel regulating device and the fuel pump in a preferred construction there is a connecting rod which at one end is pivotably connected to the control piston rod and at the other end engages in an aperture in the pump piston.

Further features and details of the invention will be apparent from the following description of two constructional embodiments which are illustrated by way of example, in the accompanying drawings, wherein:

Figure 1 is a diagrammatic longitudinal sectional view of a free-piston engine;

Figure 2 is a view, in longitudinal section, showing a slightly modified construction of the engine shown in Figure 1.

Referring to the drawings:—

The engine illustrated in Figure 1 comprises a cylinder 10 with a central outer annular chamber 11. A piston 12 is adapted to reciprocate in the cylinder and has a central annular collar 13 which projects radially into the annular chamber 11 which serves for aspirating fresh air. A fuel container 14 is connected at both ends by a line 15 to identical valve devices from which further fuel admission lines 16 lead to the ends of the cylinder 10. The cylinder 10 has outlet ports 17 which are unmasked when the piston is in the end positions, and the piston 12 has central ducts 18 which connect with inclined ducts 19 opening into the annular cylinder chamber 11. In the end faces of the piston 12 there are non-return valves 20 for the central ducts. The annular cylinder chamber 11 comprises internally and at the bottom non-return valves 21 which open into the atmosphere. Below the cylinder 10 there is a pressure container 22 which is subdivided centrally and which communicates with the working chambers of the engine cylinder 11 through two pipes 23 by way of valves 24 and non-return valves 25.

Each admission line 16 to the cylinder 10 is fitted with a needle valve 26 having a needle valve member 27 which is pressed against its seat by a spring 28.

A fuel admission regulating device operated by the collar 13 of the piston is situated above the cylinder 10. Each device contains a piston 30 which is displaceable in a cylinder 29 and projects into the annular chamber 11 and one end of which is pressed into the annular chamber 11 as far as a stop 32 by a spring 31. The other end of the piston 30 moves in the closed end chamber of the cylinder 29 which communicates with the line 16 by way of a pipe 33. Above the cylinder 29 with piston 30 there is a system 34 constructed as an oil regulating device, containing in its lower portion, in a cylinder 35, a piston 36 which is spring-loaded towards the centre of the engine and the piston rod 37 of which at one end bears against an extension of the stop 32, whilst the other end is pivotably connected to a connecting rod 38 the free end of which engages through the wall of the cylinder 29 and into a slot 39 in the piston 30. A spring-loaded plunger 40 bears on the centre of the rod and operates a suction valve 42 which is situated within a housing 41 and which connects the lines 15 and 16.

Above the cylinder 35 of the oil regulating device there is a ring pipe 43 which is connected to the ends of the cylinder and in the upper portion of which there is an adjustable throttling orifice 44. The ring pipe is connected centrally by a spring-loaded non-return valve 46. The engine also comprises combustion and compression chambers.

This engine operates in the following manner:

From the fuel container 14, fuel passes through the lines 15 to the suction valve 41, 42 which regulates the quantity of fuel for combustion in the cylinder 10. The opening of the suction valve, as illustrated at the right-hand side of Figure 1, is effected by the pumps formed of cylinders 29 and pistons 30 and which are driven by the freely reciprocated stepped piston 12, 13 in the cylinder 10, in conjunction with the regulating devices the main part of which is the oil regulating device 43. As indicated, the oil regulating device i.e. the control piston 36 situated therein is connected to the piston 30 of the piston pump by the rod 38.

When the working piston 12 moves in the direction of one of its dead centre positions, before reaching the dead centre position the pump piston 30 projecting into the fresh air suction chamber 11 is entrained by the end

face of the collar 13 of the working piston.

In order to avoid excessively hard impacts from the working piston collar 13, the pump piston 30 is provided at its abutment end with a rubber pad which is not shown in Figure 1. At the right-hand side of Figure 1, the working piston 12 and thus the pump piston 30 has moved quickly towards the right, the control piston 36 being entrained at the same time by the extension of the stop 32 in the same direction. The movement towards the right also opens the spring-loaded suction valve 43 by the rod 38.

The fuel in the line 16 and the pump cylinder 29 is sprayed into the combustion chamber 45 of the cylinder 10, by the sudden movement of the pump piston 30, from the spring-loaded needle valve member 27 which is slightly lifted from its seat by the sudden fuel pressure. The quantity of fuel is determined by the fuel regulating valve 42, i.e. the valve 42 opens as soon as the travel of the working piston 12 increases. If the travel is reduced owing to heavy load, rather more fuel will be sprayed into the cylinder since the suction valve 42 cannot be acted upon and opened by the rod 38 owing to the short working piston travel and therefore the short travel of the pump piston 30.

The oil atomised by the high pressure and the needle valve member 27 is burned in the highly compressed air in the compression chamber 45, whereby the piston is driven into the opposite position. This movement of the working piston 12 again frees the pump piston 30 from the collar 13 of the working piston, so that it returns into its initial position owing to spring action, the fuel being brought up from the container 14 through the agency of the suction valve 42. The control piston 36 which is in the oil-filled device 43 of the regulating devices, moves only slowly backwards despite release by the stop 32. The delaying of the control piston 36 is brought about because in the upper duct 43^1 of the oil regulating device there is an adjustable throttling orifice 44 through which the quantity of oil in front of the control piston 36 can flow back only slowly into the spring chamber 35^1 of the control piston 36. When the control piston 36 is operated, however, the oil can flow very quickly through the non-return valve 46 from the chamber 35^1 into the chamber in front of the control piston 36.

During the movement of the working piston 12, the piston non-return valve 20 opens approximately when the outlet slots 17 have been passed over, since the pressure in the transverse duct 19 of the piston 12 corresponds to the pressure of the compressed fresh air in the annular chamber 11 and at the same time the non-return valve 20 of the piston is relieved of pressure from the working chamber 45 by the discharge of the combustion gases.

Each transverse duct 19 extends from one side of the piston collar 13 to the opposite end face of the collar. The suction valves 21, which constantly admit fresh air into the annular chamber 11 in accordance with the way in which they are acted upon, are situated at the end faces of the annular chamber 11 of the cylinder 10. The fresh air aspirated into the annular chamber 11 is compressed and passes through the transverse duct 19 past the valve 20 into the cylinder interior 50 where it ensures efficient scavenging of the interior of the cylinder. The combustion gases flow through the outlet apertures or slots 17 which are arranged in a circle about the periphery of the cylinder 10.

While the piston is still travelling over the outlet slots 17, the pump piston 30 is again operated by the working piston collar 13 so that the completely identical control device at the left-hand side of the engine comes into action and another working stroke of the engine is affected. From the left-hand dead centre position of the engine the piston is moved into the right-hand dead centre position after injection of the fuel into the highly compressed air and after the fuel has been burnt. During this movement, the piston valve 20 closes owing to the compression occurring in the working chamber 45, so that appropriate compression of the fresh air in the working chamber is permitted.

The starting of the free-piston engine will now be described by way of example.

The free-piston engine can be started by compressed air from the pressure container 22 which is sub-divided into two chambers. At starting the chambers of the pressure container 22 are filled with compressed air until they have reached the maximum pressure during the compression in the cylinder interior 45.

Due to the ducts between the cylinder chamber and the pressure container 22, a pressure is built up in the pressure container, and this pressure corresponds to the maximum pressure occurring in the combustion chamber. Since the ducts are only of relatively small cross-section, the transmission of the pressure takes place only slowly, so that the pressure is fully reached in the pressure container only after a certain time. In order that the gases will not return to the cylinder chamber again and thereby reduce the pressure in the pressure container, non-return valves are provided in the ducts. The pressure built up in the pressure container 22 and which is to be used for starting the engine, may of course only be maintained for a certain time in order to be able to start the engine again once it has stopped.

The filling of the pressure chambers in the container 22 is effected by the non-return

valves 25 which are situated at the end faces of the cylinder 10. During the compression in the interior of the cylinder, the non-return valve 25 opens and during a working operation a small quantity of air passes into the pressure chamber 22. This quantity of air is small since it can only pass through a very narrow pipe section 23^1 to the pressure container 22. A small quantity of gas can also pass through the pipe section 23^1 into the pressure container 22 during the expansion of the burned fuel mixture. As already mentioned, the pressure container 22 is filled only until the maximum pressure prevailing in the cylinder interior 45 is reached. The filling of the pressure chambers of the container 22 is terminated as early as possible after the engine has been running for a short time. The non-return valves then remain in their initial position since the high pressure prevailing in the pressure container 22 prevents opening of the valves 25 or is in equilibrium with the pressure in the cylinder interior.

If the engine is then stopped, with the supply of fuel cut off, the engine can be restarted after a fairly long stoppage by using the compressed gas in the pressure container 22. For this purpose, at both ends of the cylinder there is a pipe 50 which communicates with the pressure container 22, subdivided into two chambers, and in each of which there is arranged a shut-off valve 24.

The narrow pipe section 23^1 for filling the pressure container also opens into the pipe 23. If at one side of the cylinder 10 the shut-off valve 24 is then opened, the working piston 12, 13 moves suddenly into the dead centre position opposite from the shut-off valve 24, the air being compressed and the oil injected, so that the first working stroke is carried out.

The first time the free-piston engine is started, the pressure chambers of the container 22 are filled by a hand pump.

Figure 2 shows a further constructional form of the free-piston engine operating on a Diesel two-stroke cycle. The construction will be described simultaneously with a description of the method of operation.

For easier understanding and in order to permit comparison with the construction shown in Fig. 1, in Fig. 2 and the following description reference numerals identical with those of the construction shown in Fig. 1 are used for identical parts the purpose of which corresponds to those of the parts used in the construction shown in Fig. 1. Therefore, there is no need to describe again those parts which have already been discussed in the description of Fig. 1 or to describe their method of operation, so that the following description will be limited substantially to the new or modified parts.

As in the case of the engine shown in Fig. 1, the fuel flows from the fuel tank 14 through the lines 15 to a suction valve 42. The opening of the suction valve 42, as illustrated at the left-hand side of Figure 2, is effected by the pistons 46 of the pumps 47 which are driven by the compressive pressure of the freely-reciprocating stepped piston 12, 13 occurring in the cylinder 10, in conjunction with a regulating device 48. The regulating device 48, i.e., the control piston 49 situated in it, is connected to the piston 46 of the pump 47 by the connecting rod 50^1 which latter in this construction is also arranged with one end in a slot 51 in the piston 46. The other end of the rod 50^1 is pivotally connected to the end of the piston rod 52 of the spring-loaded control piston 49.

If the engine is running under uniform load, the working piston 12, 13 carries out a quite specific stroke in the cylinder 10 and thus a specific end pressure is produced in the compression chamber 45. The regulating device 48 communicates through a non-return valve 53 and a pipe 54 with the cylinder 10, so that the end pressure in the compression chamber 45 is produced in the cylinder of the regulating device 48, whereby the piston 49, in conjunction with the spring 55, takes up a specific position in the cylinder 56. By means of an adjustable throttling orifice 57 some products can escape, so that at another engine load or another end pressure in the compression chamber 45, the piston 49 can take up the relevant new position in the cylinder 56. The position of the piston 49 in the cylinder 56, however, determines the quantity of fuel supplied to the engine, owing to the fact that the suction valve 42 is opened or closed earlier or later by the pump piston 46. The fuel pump 47 is operated by the compression pressure which acts on the larger part 58 of the piston 46 in opposition to the action of the spring 59, so that the pump operates only in the last part of the compression process, i.e., shortly before the dead centre position of the piston 12, 13.

The fuel in the pipe 60 and pump cylinder 61 is sprayed into the combustion chamber 45 by the movement of the pump piston 46 from the spring-loaded needle valve member 62 which is lifted slightly from its seat by the fuel pressure.

The oil atomised by the high pressure and the needle valve member 62 is burned in the highly compressed air in the combustion chamber, so that the working piston is moved into the opposite position. This movement of the working piston 12 relieves the spring-loaded pump piston 46, 58 from the pressure of the compressed air and the pump piston resumes its initial position.

During this period, fuel can again be brought up or aspirated by the return of the pump piston 46 from the container 14 into the pump cylinder 61 and into the pipe 60.

During the movement of the working piston 12 towards the right at the instant when the outlet slots 17 are passed over, the piston non-return valve 20 opens and the same process occurs as already described above with reference to Figure 1.

This continually repeated operation is a two-stroke Diesel cycle, since the suction and expelling strokes are dispensed with. The changing of the cylinder contents is effected after expansion in the immediate vicinity of a dead centre, so that at the beginning of the compression stroke the waste gas is removed and the fresh air introduced.

WHAT WE CLAIM IS:—

1. A free-piston engine for producing rectilinear mechanical oscillations by means of a freely-moving reciprocable working piston which is bilaterally stepped and the two reduced-diameter ends of which engage in ends of a working cylinder which are associated with the piston ends and form the working chambers, while a central, larger-diameter collar part of the working piston forms a common driving means for control members of two Diesel two-stroke parts of the engine and is surrounded by an annular cylindrical chamber which forms a fresh-air admission chamber and is provided with air-inlet valves controlled by the piston collar part, the engine being characterised by the provision of air admission ducts formed centrally in the working piston and having non-return valves and leading to the end faces of the piston, and transverse ducts which are connected to the air admission ducts and start in front of the piston collar part and open behind it into the said annular chamber.

2. An engine as claimed in claim 1, wherein the said control members acted upon by the collar of the working piston are, in addition to the air inlet valves, the pistons of pumps arranged in a fuel supply line, the driving of which pumps and the consequent fuel pressure effecting the injection of fuel into the working chambers of the engine preferably by opening a spring-loaded needle nozzle valve.

3. An engine as claimed in claim 2, wherein control pistons, by means of which self-closing fuel admission valves in the fuel lines to the cylinder are to be opened, are driven through the agency of the pump pistons operated by the collar of the working piston.

4. An engine as claimed in claim 3, wherein the control pistons for the fuel admission valves are movable in the opening direction of the valves at the same speed as the pump pistons and are movable more slowly in the opposite direction by the action of a flow-delaying device associated with them.

5. An engine as claimed in claim 4, wherein the flow-delaying device for the control pistons is an oil circulation or regulating device which permits the movement of the pistons in the opening direction of the fuel admission valves by automatic opening of a non-return valve but delays the piston movement in the opposite direction for closing the non-return valve and the passage of oil through a throttling orifice, which, preferably is adjustable.

6. An engine as claimed in any of the preceding claims, which is provided with an energy-storing means which, preferably, is in the form of a pressure container connected to the ends of the working cylinder and is chargeable by the engine and also from the outside, the arrangement being such that the engine can be started from a stopped condition with its working piston in any desired position.

7. An engine as claimed in any of the preceding claims 2 to 6, in which the annular fresh-air admission chamber contains only the air outlet valves controlled by the collar of the working piston, and wherein the pump pistons which effect fuel admission, preferably by way of needle valves, into the cylinder ends are adapted to be acted upon through a connecting pipe from the working chambers of the engine, the pistons which control the movement of the fuel admission valves in the fuel admission line and are displaceable in cylinders being adapted to be acted upon through pipes which are also connected to the working chambers of the engine.

8. An engine as claimed in any of the preceding claims, wherein the pistons which effect the injection of fuel and are displaceable in a cylinder have two parts of different diameters, the larger part facing the engine cylinder being loaded by a spring in the direction opposite to its admission direction, whilst the smaller part extends into a corresponding cylinder chamber which is connected to the fuel admission line and from which the fuel to be injected into the engine is always displaced.

9. An engine as claimed in any of the preceding claims 5 to 8, wherein the control device for the fuel admission valve in the line to the engine cylinder, which control device consists of a cylinder with a piston displaceable in it, contains a non-return valve which permits unhindered pressure action on the control piston and which in conjunction with an air throttling orifice provided in the cylinder delays the movement of the control piston in the opposite direction.

10. An engine as claimed in any of the preceding claims 4 to 9, in which between the fuel regulating device and the fuel pump there is a connecting rod which is pivotably connected at one end to the control piston rod and at the other end extends into an aperture in the pump piston,

11. A free piston engine, substantially as described with reference to Fig. 1 or Fig. 2 of the accompanying drawings.

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941,453 COMPLETE SPECIFICATION
1 SHEET

This drawing is a reproduction of the Original on a reduced scale.

Fig.1

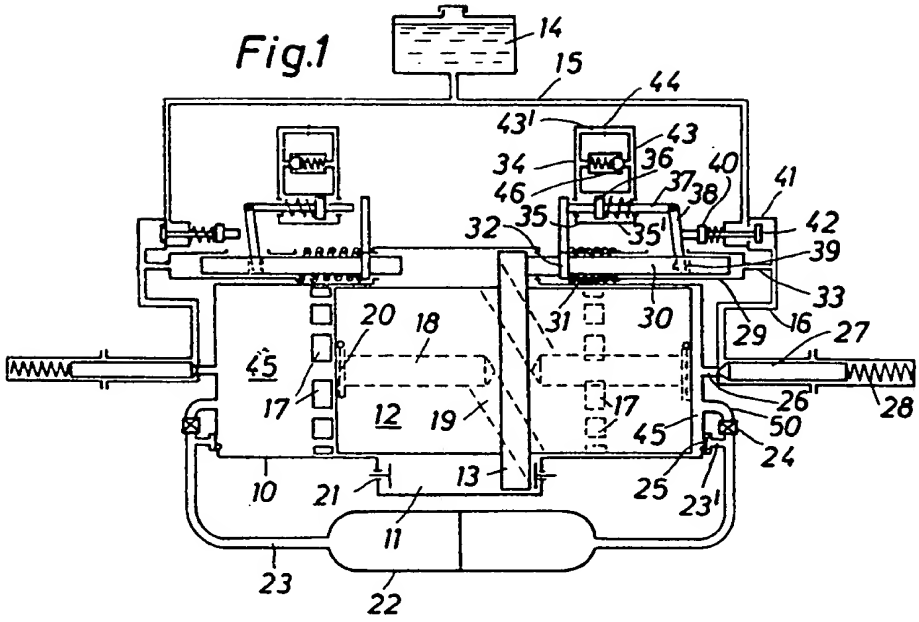

Fig.2